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Review on Comparative Analysis of Symmetrical, Unsymmetrical and Diagrid Multistory Building using Staad pro.

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Abstract: ***This review paper involves the study of various aspects of analysis and design of multi storey residential building by using STAAD. Pro. Structural designing requires a detailed structural analysis on which the design of the structure is based. But it is not always possible to do in manual calculation hence the need for programming tools was found. For which several of power tools were formed, among which the most widely used one is STAAD.***
Keywords: Analysis, Design, STAAD PRO, Residential building, gravity load, shear force, bending moment and axial force.

I. INTRODUCTION

Infrastructure is the basic way to represent the level of development of a country, among which the major share is shared by the high raise buildings which are not possible without a structural designer.

As the world is transforming the high rise buildings are in a great demand which is to be fulfilled without sacrificing any of the three factors, cost, time and safety. Achieving this is not possible with manual calculation hence to counter this we need highly advanced ways of computation, which can allow you to calculate and analyses the structural variables like shear force, nodal displacement, bending moment etc.

The answer to such problems is Staad. Pro which provides a much faster approach to structural analysis and designing with chances of minimum errors.

There has been several research conducted comparing the results from Staad. Pro to the manually calculated results, which all support the use of Staad. Pro over manual the one. Staad. Pro is a much better way to analyses the complicated load combinations and is quite versatile [1].

II. BASICS OF MULTI STOREY BUILDING

The structural design of a building should ensure that the building can stand safely, operate without excessive deformation or movement that could lead to fatigue of structural elements, cracks or failure of fixtures, fittings or partitions, or failure. Inconvenience to occupants. It must take into account the movements and forces due to temperature, creep, cracks, and imposed loads. It must also verify that the design is nearly buildable within acceptable manufacturing tolerances of the materials. It must allow the architecture to function and the building services to adapt to the building functionally (ventilation, lighting, etc) [2]. This project work is to analyze a Multi storeyed building for different load combinations using STAAD Pro software. Based on the analysis, the design of the structure is done mainly following IS specifications.

III. BASICS OF SYMMETRICAL BUILDING

In these types of buildings, reinforced concrete frames are provided in both principal directions to resist vertical loads and the vertical loads are transmitted to vertical framing system i.e., columns and Foundations. This type of system is effective in resisting both vertical & horizontal loads. The brick walls are to be regarded as non-load bearing filler walls only. This system is suitable for the multi-storied building which is also effective in resisting horizontal loads due to the earthquake. In this system the floor slabs, generally 100-150 mm thick with spans ranging from 3.0 m to 7.0 m. In certain earthquake prone areas, even single or double storey buildings are made framed structures for safety reasons. Also the single storey buildings of large storey heights (5.0m or more) , like electric substation etc. are made the framed structure as brick walls of large heights are slender and load carrying capacity of such walls reduces due to slenderness [3].

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A. *Asymmetric Buildings*

Asymmetric buildings with centers of stiffness and strength being different from the center of floor mass, respond to earthquake excitation in coupled modes, producing both lateral and torsional motions. Such buildings as reported by many researches [4-8] are highly vulnerable due to the torsional response. The position of the stiffness and strength centers towards the floor mass center could highly affect the torsional response. The torsional provisions of codes are based on the assumption that the stiffness of the RC walls can be estimated with some degree of accuracy prior to strength allocation, and will not be affected by the subsequent strength assignment process.

B. *Diagrid Building*

The diagrid structural system can be defined as a diagonal members formed as a framework made by the intersection of different materials like metals, concrete or wooden beams which is used in the construction of buildings and roofs. Diagrid structures of the steel members are efficient in providing solution both in term of strength and stiffness. But nowadays a widespread application of diagrid is used in the large span and high rise buildings, particularly when they are complex geometries and curved shapes [9].

IV. PROBLEM IDENTIFICATION

Previous studies on the torsional behaviour of buildings focused mostly on single-storey shear configurations. Results and conclusions from these studies can be extended to multi-storey buildings only under two conditions:

1) The stiffness of the resisting elements from one storey to another must bear a constant ratio over the height of the building.

2) The centers of mass of the floors must lie on the same vertical line, i.e. building must be regular in elevation. These conclusions have influenced subsequent studies (Hejal and Chopra 1987), which have focused on the response of single story and multi-storey irregular building configurations that are regular in elevation.

The seismic behavior of these structural systems is reasonably understood and many simplified analysis techniques have been developed for use in design [10-15].

V. LITERATURE REVIEW

1) *NorbertRadics, Rigidity of multi-story buildings (2000):* Bolker and Crapo gave a graph theoretical model of square grid frameworks with diagonal rods of certain squares. The problem of one-story buildings in special cases can be reduced to the planar problems. In this work the general case of one-story buildings will be considered and the results will be generalized to the case of multi-story buildings.
2) *B.G. Birajdar , S.S. Nalawade, Seismic analysis of buildings resting on sloping ground (2004):* Results from seismic analyses performed on 24 RC buildings with three different configurations like, Step back building, Step back Set back building and Set back building are presented. 3 –D analysis including torsional effect has been carried out by using response spectrum method. The dynamic response properties i.e. fundamental time period, top storey displacement and, the base shear action induced in columns have been studied with reference to the suitability of a building configuration on sloping ground. It is observed that Step back Set back buildings are found to be more suitable on sloping ground.
3) *C.V.R. Murty, Rupen Goswami, A. R. Vijayanarayanan, Vipul V. Mehta, Some concepts in earthquake behaviour of buildings (2012):* This book explains concepts in behaviour of buildings during earthquakes. The book dwells on basic concepts in earthquake resistant design of buildings, first describes these at a conceptual level and then articulates further with numerical examples. It is an attempt to respond to some of the frequently asked questions by Architects and Structural Engineers regarding behaviour of Reinforced Concrete (RC) and Steel buildings under the action of lateral loads, especially during earthquakes. Since most buildings built in India are made of RC, the dominant set of examples used is of RC buildings. But, with no loss of generality, the broad concepts discussed in this document are valid for both RC and Steel buildings. Also, the discussion is limited to normal buildings without any special devices, like base isolation and other energy absorbing or dissipating devices.
4) *Ankesh Sharma, Biswobhanu Bhadra, Seismic analysis and design of vertically irregular RC building frames (2013):* This paper is concerned with the effects of various vertical irregularities on the seismic response of a structure. The objective of the project is to carry out Response spectrum analysis (RSA) and Time history Analysis (THA) of vertically irregular RC building frames and to carry out the ductility based design using IS 13920 corresponding to Equivalent static analysis and Time history analysis.. Three types of irregularities namely mass irregularity, stiffness irregularity and vertical geometry irregularity were considered. According to our observation, the storey shear force was found to be maximum for the first storey and it decreases

to minimum in the top storey in all cases. The mass irregular structures were observed to experience larger base shear than similar regular structures.

5) *George Georgoussis, Approximate Seismic Analysis of Multi-story Buildings with Mass and Stiffness Irregularities (2015):* An approximate analysis is presented for multi-story setback buildings subjected to strong ground motions. Setback buildings with mass and stiffness discontinuities are common in modern architecture and quite often they are asymmetric in plan. Such buildings are classified by Eurocode 8 (EC8-2004) and codes from other countries as irregular structures, which specify a full 3-dimensional dynamic analysis.
6) *Juan C.Reyes, Extending modal pushover-based scaling procedure for nonlinear response history analysis of multi-story unsymmetric-plan buildings (2015):* The modal-pushover-based-scaling (MPS) procedure has been developed for appositely selecting and scaling earthquake records for nonlinear response history analyses (RHAs) of multi-story symmetric-plan and single-story unsymmetric-plan buildings. This procedure is extended here to unsymmetric-plan buildings with significant torsional response under bi-directional earthquake excitations. The accuracy of the procedure is evaluated by using three-dimensional computer models of nine unsymmetric-plan buildings with 5, 10 and 15 stories. These models were subjected to nonlinear RHAs considering sets of seven far-field records selected and scaled according to the extended modal-pushover-based-scaling (EMPS) procedure.
7) *S.D.Uttekar, C.R.Nayak, "A Review on Seismic Response of RC Building on Sloping Ground" (2016):* Seismic analysis is the calculation of the response of a structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent. The aim of this paper to study the response of RC structure on slopping ground. To evaluate the response of building by using linear analysis and non linear analysis. The analysis will be carried out on SAP 2000 with help of guidelines following code I.S 1893:2002 (part I), FEMA 356. The seismic response on sloping ground is quite different as compare to seismic response on plain ground.
8) *Ravindra Navale, Analysis of Unsymmetrical Building Resting on Sloping Ground by Dividing In 2D Frame (2017):* When a building is rested on sloped ground, there are many possibilities of having short and long columns in same structure. During earthquake shaking, all columns move horizontally by the same amount along with the floor slab at every different level which may effects damage to the structure. In this study, the building is analyzed in terms of 2-D frames considering different floor heights and number of bays using a structural analysis software tool ETABS. The analysis where carried along both x and y direction. For the comparison of results, various graphs were drawn for bending moment bending moment developed for the frames on plane ground and sloping ground. From these results, we have the summary of the simultaneous effects on short and long columns when present in the structure. Also,the results had been compared for different bay systems on plane and on a sloping ground for the increment of every story in frame. And finally, the structure would be analyzed and designed on sloping ground in seismic zone.
9) *Ebrahim Nazarimofrad, Fuzzy control of asymmetric plan buildings with active tuned mass damper considering soil-structure interaction (2018):* In recent decades, many researchers have conducted studies on structural control to improve the safety and serviceability of high-rise buildings or towers against earthquake and strong wind. Since most buildings have a sort of asymmetric plan they experience torsional effects when subjected to earthquake and subsequently the torsion would increase the structural response. Also, such buildings might be constructed on soft soil where the Soil-Structure Interaction (SSI) influence would be important.
10) *RaminK. Badri, Assessing the importance of deterioration properties for the design decision-makings of low-rise asymmetric reinforced concrete buildings (2018):* Engineers may make various decisions based on the engineering judgment while they design a building, or may choose different methods for modeling the structural components, especially the way by which the deteriorating behavior of elements should be incorporated. Such decisions cause the engineering demand parameters (EDPs) to depend on the deterioration properties of a building considered in a seismic performance assessment. It is important to know how much those properties are going to be effective on or valuable for designing of low-rise asymmetric RC buildings, or how they affect the design decision makings. For the example buildings, the seismic performance is evaluated by performing the incremental dynamic analysis (IDA) and monitoring the lateral deformation versus the load-resisting capacities of the models. By introducing a new criterion, the influence of the deterioration properties on the seismic performance of models is then assessed, providing the results for both torsionally-stiff and torsionally-flexible models. Although the deterioration affects the torsionally-stiff models more rapidly than the torsionally-flexible types, its impacts depend on the value of hysteretic model parameters. In contrary to the torsionally-flexible models, the influence of deterioration on the torsionally-stiff buildings is

sensitive to the building asymmetry. However, the variation of deterioration rate is very significant for the torsionally-flexible models. So, it is important to make careful design decisions for reducing the undesirable effects of the deterioration.

11) *Mohammad M.Zafarani, A new supervisory adaptive strategy for the control of hysteretic multi-story irregular buildings equipped with MR-dampers (2020):* The simplified one-story asymmetric models cannot simulate the inelastic performance of controlled irregular multi-story frame type buildings subjected to extreme dynamic loadings, especially when the effect of higher modes on distribution of engineering demand parameters (EDPs) over the height of the structures is an important design factor. In the present study, controlled nonlinear seismic response of coupled translational–torsional irregular multi-story smart buildings is investigated. In order to control such nonlinear systems, a new robust adaptive model-based controller is introduced. This new adaptive model-based strategy, due to using adjustable parameters such as instant stiffness, could well consider the nonlinear behavior of the structure and act more precisely in controlling the torsional behavior of Magneto-Rheological (MR) dampers-equipped multi-story torsional buildings.
12) *Zheng Tan, Numerical study on collapse-resistant performance of multi-story composite frames under a column removal scenario (2021):* In practice, when building structures are subjected to local damage caused by extreme loads, all stories above the failure column consequently deform and play a major role in the internal force redistribution and rebalancing for resisting the external load. However, because of the high cost and laboratory space constraints, most existing experimental tests on progressive collapse are primarily focused on single-story sub-assemblages. In a previous experimental work, to investigate the collapse performance of a multi-story composite frame, a 1/3 scale three-story composite sub-frame with top and seat with double web angle (TSDWA) connections was tested quasi-statically. However, whereas many factors have a significant influence on the progressive collapse performance, the corresponding experimental data proved too limited to allow their analysis.
13) *Kai Qian, Numerical evaluation of the reliability of using single-story substructures to study progressive collapse behaviour of multi-story RC frames (2021):* Progressive collapse is a global failure for a multi-story building. All stories above the removed column will consequently deform and help redistribute the loads initially withstood by the removed column. However, due to cost and excessive time to be involved, the majority of existing experimental researches regarding progressive collapse rely on single-story beam-column substructures or sub-assemblages. To date, how to use the results from single-story substructures or sub-assemblages to fully or confidently study the behavior of multi-story building is still unclear. Thus, it is imperative to investigate the relationship between the results of single-story substructures and the real behavior of multi-story buildings.
14) *Vasiliki G.Terzi, Influence of soil structure interaction effects on the real elastic axis of asymmetric buildings (2021):* Structural eccentricity plays an important role in the seismic design of buildings. According to various seismic design codes, it is one of the parameters which define whether a building may be considered as regular in plan. Structural eccentricity is defined as the distance between the center of mass and the center of rigidity. However, the center of rigidity is rigorously defined in single story buildings and in some special classes of multi-story buildings, e.g. isotropic ones, under the assumption of fixed based conditions. The present paper deals with single story and multistory asymmetric buildings that possess a real elastic axis under the assumption of fixed base condition and examines the existence or not of an elastic axis under soil structure interaction effects.
15) *Vasiliki G.Terzi, Optimum torsion axis in multistory buildings under earthquake excitation: A new criterion based on axis of twist (2021):* The elastic axis is essential for the definition of structural eccentricity, which significantly affects the torsional behavior of buildings. However, it can be determined straight-forwardly in single-story and some special cases of multi-story buildings. Therefore, for the majority of multi-story buildings, the notion of optimum torsion axis has been introduced, according to which, the torsion of the building is considered optimum when the sum of squares of the floor torsional angles is minimum under horizontal forces passing through this axis. The existing determination procedures refer to the application of static horizontal forces and static torsional moments at each story. The present study proposes a new criterion, which approaches the optimum torsion axis by the prism of axis of twist and requires the sum of floor translational displacements of the axis to be minimal.
16) *AnwarShamkhi, Hybrid active control of adjacent buildings interconnected by viscous dampers utilizing type-2 fuzzy controller considering soil-structure interaction (2021):* Viscous dampers (VDs) connecting adjacent multi-story buildings are significantly useful not only for preventing severe earthquake-induced pounding, but also for mitigating the response of buildings. In the current study, in addition to utilizing viscous dampers, enhanced hybrid active tuned mass dampers (EHATMDs) are used at the top of asymmetric buildings and active tendons (ATs) are used at the sixth floor of symmetric buildings, while all these buildings are interconnected by VDs. The interval type-2 fuzzy logic controller (IT2FLC)

is employed to produce real-time active forces applied to the actuators of EHATMDs and ATs. Moreover, soil-structure interaction (SSI) effects are considered. The aim is to assess the performance of all the mentioned controllers in mitigating both the translational and torsional responses of structures rested on soft soil. To reach these goals, three different layouts of adjacent buildings, including asymmetric and symmetric buildings, are taken into account. The results showed that the layout where asymmetric buildings were controlled by VDs in both main directions had the highest performance.

17) *Ljiljana Vasilevska, The effects of changes to the post-socialist urban planning framework on public open spaces in multi-story housing areas: A view from Nis, Serbia (2021): This* study considers how changes to the post-socialist urban planning framework have affected the treatment of public open space in the transformation of existing mass-housing areas and newly developed multi-story housing areas for the city of Nis, Serbia. The study focuses on quantitative and qualitative changes as well as the physical characteristics of public open spaces, evaluating environmental comfort, safety, accessibility, privacy and intensity of social interactions. The investigation is based on a comparative analysis of three case studies in Nis, which are representative of different developmental, institutional and planning periods. The research indicates a regressive approach in the planning for and treatment of public open space. It also suggests that within the limited economic capacity of local authorities, investors and buyers, the market-oriented post-socialist urban planning framework can lead to spatial and functional fragmentation in housing areas and the degradation or disappearance of not only the public spaces but of open spaces in general.
18) *Vasiliki G.Terzi, Elastic axis of special classes of buildings under earthquake excitation (2021):* In the present paper the existence of a stable vertical axis of twist in single story and isotropic multistory buildings is investigated. For this purpose, a torsional base excitation is applied at the buildings base and the equation of motion is transformed in the frequency domain. By using the diaphragm constraint equations, analytical formulae are developed which provide the location of the twist axis which is called dynamic elastic axis. It is proved that the coordinates of the dynamic elastic axis depend on stiffness, mass, damping and excitation frequency. Numerical examples are presented. All the results produced by using the developed equations are compared with the coordinates of the elastic axis derived by the application of static forces. The divergence of the two methods is discussed in detail.
19) *MinjaeShin, A procedure for automating thermal zoning for building energy simulation (2021):* Although many previous studies have addressed the accuracy of building energy simulations, very few studies of this subject have mentioned the importance of Heating, Ventilation, and Air-Conditioning (HVAC) thermal zoning strategies to sustainable building design. In addition, the building energy standards and guidelines related to building energy simulation recommend that only a core and perimeter thermal zoning strategy be used to reduce the total number of thermal zones in a model. However, although this simplifies modeling, it can lead to too many thermal zones in the building energy model of a multi-story building, or in some cases too few zones, which can impact the model's accuracy. Therefore, the aim of this study is to develop a new thermal zoning process for building energy simulation called the “grid/cluster method.” that can be applied automatically to whole-building energy simulations of multi-zone commercial structures.
20) *Malla Karthik Kumar, Vanka Srinivasa Rao, Kusuma Sundar Kumar, Study on earthquake resistant buildings on ground surface by using ETABS (2022):* The design of such structure may appear to be more complex. These buildings are designed in such a way that its every component must resist two types of loads, i.e. vertical Load due to gravity, and lateral load due to earthquake and wind. The components of horizontal framing system are slab and beams, which transfer vertical load to vertical framing system and in the vertical framing system there are beams and columns, which transfer lateral load to the foundation. Besides the Himalayan region and the Indo-Gangetic plains, even the peninsular India is prone to severe earthquakes as clearly.
21) *YanFeng, Development and evaluation of a VR research tool to study wayfinding behaviour in a multi-story building (2022):* Although understanding wayfinding behaviour in complex buildings is important to ensure pedestrian safety, the state of the art predominantly investigated pedestrian movement in simplified environments. This paper presents a Virtual Reality tool – WayR, that is designed to investigate pedestrian wayfinding behaviour in a multi-story building under both normal and emergency situations. WayR supports free navigation and collects pedestrian walking trajectories, head movements and gaze points automatically. To evaluate WayR, a VR experiment consists of four wayfinding assignments were conducted.
22) *Mohsen Zaker Esteghamati, Reliability-based assessment of progressive collapse in horizontally irregular multi-story concrete buildings (2022):* Structures’ resistance against progressive collapse varies depending on their design and taxonomy. However, despite numerous studies addressing the impact of geometric configuration, limited attention is given to the effect of irregularity. This study presents a reliability-based approach to evaluate the effect of horizontal irregularity on the progressive collapse potential of seismically designed concrete buildings. Incremental dynamic analysis is performed on three-dimensional

nonlinear finite element models of six prototype buildings with different levels of horizontal irregularity subjected to four column removal scenarios.

23) *RaminK. Badri, Rational decisions for seismic collapse-prevention design of low-rise asymmetric RC buildings considering deterioration properties (2022):* This research points to an essential need to develop a well-defined design method considering the deterioration properties of structural elements. Although the seismic design provisions have changed over the past decades, they ignore the deterioration effects and the collapse probability of frames designed to the latest specifications still exceed the expected norms. The issue becomes more significant for asymmetric buildings where the lateral load-resisting elements behave differently. To this end, several sensitivity analyses are performed using a new index to show the importance of deterioration sources on the seismic performance of analysis models.

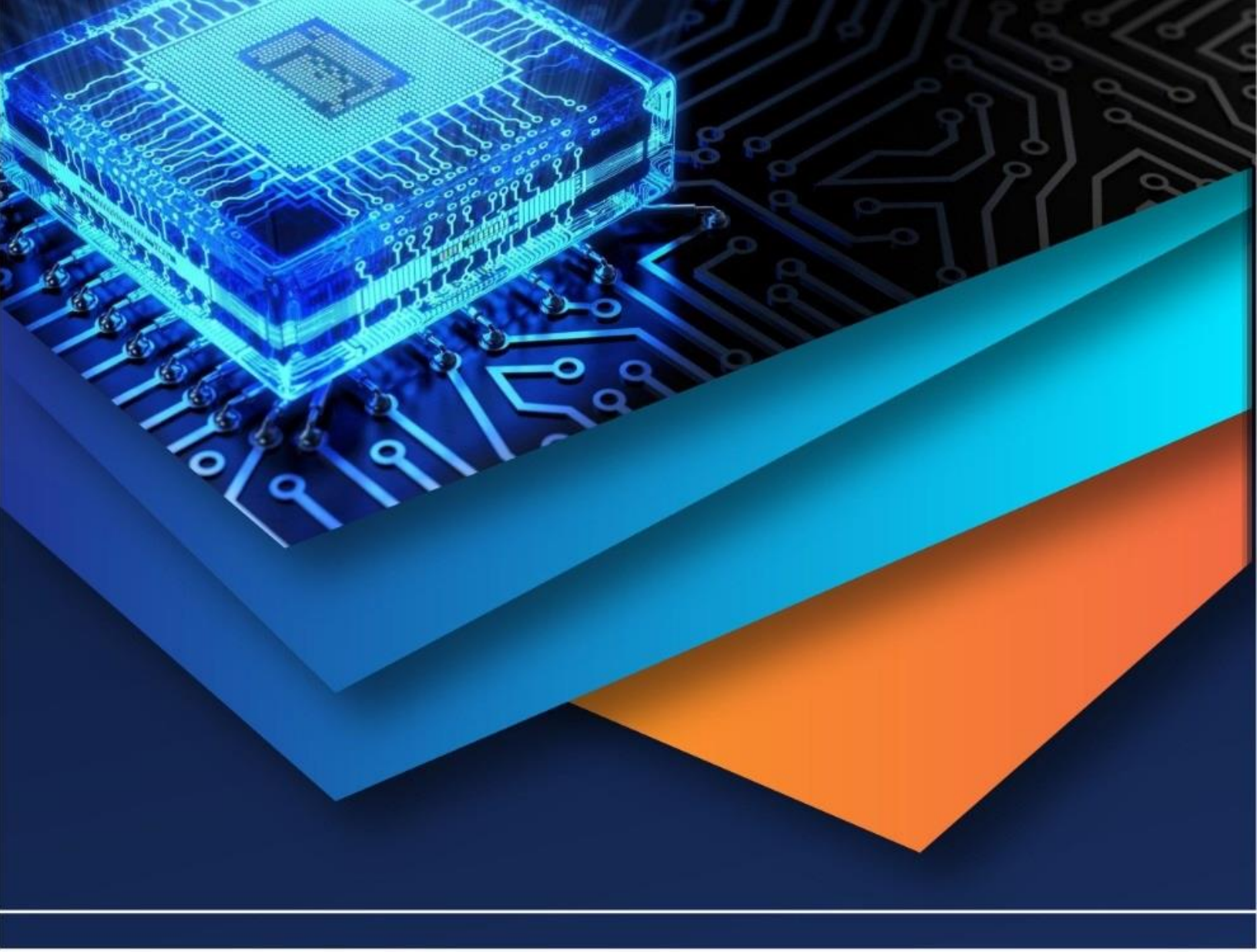
VI. CONCLUSION

Planning, analysis and design of any multi-storey residential building will be very difficult, time consuming and uneconomical if it is done manually.So it can be concluded that software like STAAD.pro should be used in the analysis and designing of any multi storey building to save meet the high speed of work and to avoid tedious manual calculation as well as to ensure the safety and economy of the work. The analysis and design were done according to standard specifications using STAAD . Pro for static and dynamic loads. The dimensions of structural members are specified and the loads such as dead load, live load and wind load are applied. Deflection and shear tests are checked for beams, columns and slabs. The tests proved to be safe. Both theoretical and practical work has been done. Hence, I conclude that we can gain more knowledge in practical work when compared to theoretical work.

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